Effectiveness of digital contact-tracing applications on COVID-19 pandemic

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ABSTRACT

Currently the entire globe is affected by the COVID-19 pandemic. The virus keeps spreading and governments tighten their safety measures. Many app designers have tried to develop an mobile application in order to execute contact tracing more efficiently. The World Health Organization recommends a combination of measures: rapid diagnosis and immediate isolation of cases. However, there are likely many cases of undetected SARS-CoV-2 infection. Several mobile applications have been proposed to the Dutch government, yet one fits the expectations. In this article, we explore the effectiveness of such contact-tracing apps and explain how to reach the highest possible effectiveness such applications.

CCS CONCEPTS

• **General and reference** → **Cross-computing tools and techniques**; *Verification*

KEYWORDS

ACM proceedings; SARS-CoV-2; Coronavirus; COVID-19; Effectiveness; Contact-tracing.

INTRODUCTION

The issue capturing global attention in the recent months is the COVID-19 pandemic, causing great disruption throughout the world in terms of health care and economy. Many governments have since the outbreak opted for an approach to combat the virus through limiting all social interactions within society (commonly referred to as a lockdown), putting a halt to the spread of the virus at the cost of national economy. In the long term, this approach is not sustainable. However, leading to the need to find ways to reduce restriction on social interaction in all aspects of society without losing grip of the spread of the virus. To this end, the Dutch government has suggested the nation-wide deployment of an application designed to predict/detect persons infected with the Coronavirus, Enabling them to accurately manage the virus' impact on society without the need for a dramatic type of lockdown. The need for such an app is still being questioned, since it brings a lot of difficulties with it, regarding the violation of the Dutch privacy legislation. In [10] is explained that we need a mobile contact-tracing app to urgently support health services to control the COVID-19 transmission, target interventions and keep people safe.

The focus of this article therefore lies solely with the effectiveness of such contact-tracing apps. The objectives of the article will be to determine through literary research what the relevant requirements are to the problem and what exactly the desired effectiveness of the application is in order to meet its requirements. Finally, the objective of practical research done thereafter will be to determine what type of implementation of the app satisfies the requirements set by the results from literary research.

In this article we present our insights on the effectiveness of digital contact-tracing applications in context of the COVID-19 pandemic. These insights lead to several recommendations on how to reach the highest possible effectiveness when discarding influenceable factors like privacy. The state-of-the-art applications' values will be reviewed together with the developers' views on their product. Simulation models will be analysed in order to compare and give structured critique on them to conclude what could be missing in these models. Together with knowledge gained from related works, the article will present a well-structured argument.

We expect the findings of the article to bring us a well structured list on how to achieve the highest effectiveness of a digital contact-tracing application in context of the COVID-19 pandemic. The article contributes to (i) an understanding of optimal effectiveness for digital contact tracing apps and (ii) to the problem of designing a functional digital app in order to combat the COVID-19 pandemic.

RELATED WORKS

In order to give clear and reliable conclusions the findings need to be compared with already existing knowledge. We have gained knowledge on the following topics: effectiveness of contact-tracing; application of technology; simulation models and state-of-the-art mobile apps. This knowledge will help us focus on the critical aspects of the applications' effectiveness and create a well structured view on what is necessary to reach this objective.

Effectiveness of contact-tracing

The effectiveness of contact-tracing has several coherent factors. The mobile application which will be launched should work properly to begin with. The app will therefore need to reach certain benchmarks.

One of these benchmarks is the app adoption rate [8] which the application will need to achieve. The adoption rate is the percentage of the population which is required to properly use the app in order to suppress the epidemic [11]. According to [12], if 70% of the population uses smartphones (assuming that there is no app use there for children aged under 10 and the fact that people aged over 70 have a low smartphone use), and epidemic like COVID-19 can be suppressed with 80% off all smartphone users using the digital contact-tracing app, which is equal to 56% of the total population. Contact-tracing using smartphones can be beneficial even with a partial adoption among the population [12]. In order to contain the spread, the adoption rate should at least be higher than 60% [8]. The developers of DCTS [9] think this percentage must be even higher, the DCTS (Digital Contact Tracing System) needs a broad acceptance among the population, which would be more than 70% in order to have an impact.

R0 dingen toevoegen?

Whenever an person has been in contact with an infected individual, the application will send a message to the possible infected individual about the situation [9]. This message should bring insights to the user and provide it of clear advice and instructions. In order for this method to be as effective as possible, a psychologist should be consulted about the exact wording and information of the notification, in order to achieve the desired effect [9]. This should highly increase the probability of the user succeeding in what the notification tells them, which is crucial for reducing the spread of the virus.

When looking at the effectiveness of contact tracing, the latent period (the time interval between when an individual is infected by a pathogen and when he or she becomes capable of infecting other susceptible individuals [13]) needs to be taken into account. According to [14], whenever the detection time of an infected person is fixed, a too large latent period (larger than the detection time) results in a situation where every infected person is detected before transmitting the infection, so tracing need not prevent any transmission. Effectiveness may therefore be very sensitive to the latent period, especially with little variation [14]. The sensitivity may be especially large in the case of single-step tracing [10, 15, 16]. This could be solved in means by introducing a variable detection time [14]. The DCTS [9] proposes to apply second order tracing. The DCTS is being evaluated together with intervention strategies, and these results are being crosschecked using both deterministic and Monte Carlo based approach models [17]. Based on these models, applying only first order contact tracing might not be enough. Therefore, [9] wants to enable both first and second order tracing. "Tracing second order contacts increases significantly the number of traced potentially infected people. If every direct and indirect contact stayed in quarantine, a huge percentage of the population would be affected" [9].

Because the digital contact tracing applications are often installed on the user's mobile phone, there occur several limitations [8]. Errors may occur due to the assumption that the distance can be estimated from the measured attenuation. Smartphones might share certain hardware components. Next to that, the smartphone might not be carried on the body, it could be stored in a purse, or left in the car.

Application of technology

Bluetooth [1, 2, 3] BLE [4, 5, 6, 7, 8, 9] (de)centralised approach [9] (find source for centralised approach).
Location detection methods. Geluid
Research for Bluetooth approach: BLE or Original.
(de)centralised approach
Limitations – mac address, energy consumption, Bluetooth limitations.

The main focus of a digital contact-tracing application is tracing the user and collecting data on contacts within the social distancing barriers. There are several technical possibilities in order to realise this, which will be discussed. Which approach is best applicable for the highest effectiveness and what are the possible limitations?

Contact tracing requires the device on which the application is installed to track the user's location, or at least, detecting every individual contact with another user. Several solutions have been proposed. Solutions included WiFi MAC address sniffing [20], GPS [8, 9, 20, 21, 22], cellular network geolocating [24, 25] and using mobile network data [9]. Due to the fact that it is supposed to work indoors as properly as outdoors, these solutions are not reliable [9]. Many believe that Bluetooth tracing is the most suitable and has also been demonstrated effective for proximity detection [4, 18]. Because Bluetooth has an effective range of round 25 metres, the use of signal strength can identify whenever another device is within the 2-metre rule according to social distancing measurements [4, 18, 25]. Therefore, many papers [1, 2, 3, 4, 5, 6, 7, 8, 9, 18, 19, 20] propose the use of Bluetooth for proximity detection.

The use of Bluetooth can be split up in two main methods. Several papers propose the use of ordinary Bluetooth [1, 2, 3, 18] whereas others propose the use of Bluetooth Low Energy (BLE) [4, 5, 6, 7, 8, 9, 19]. BLE seems to take the upper hand because of its benefits. BLE should make sure that the battery is drained by no more than 5% by performing contact tracing, and that in a situation with 100 devices in close range [9]. The probability of the devices detecting each other successfully within 10 seconds is close to 100% [9].

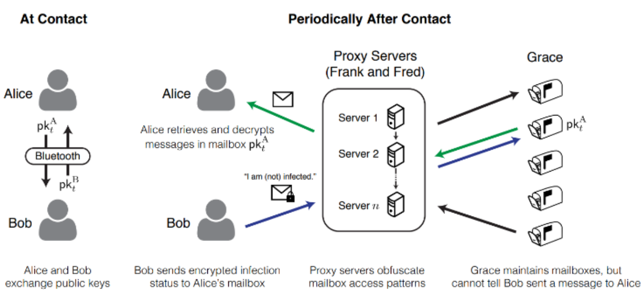

Figure 1: Overview of contact tracing based on private messaging systems. When Alice and Bob are near each other they exchange public keys as tokens. They then periodically encrypt (using each other's public key, followed by the public keys of the proxy servers) a message indicating their infection status, and send it to the proxy server. They also periodically query the proxy server for messages posted to the mailboxes corresponding to their public keys to find out whether they have been exposed to the virus [1].

TraceTogether [1] is currently the best possible example of a working digital contact-tracing application. It makes use of ordinary Bluetooth [needs to be finished]

When situated in a crowded scenario where multiple phones are present, the application will use larger delays than specified in the BLE approach, which will lead to six times the energy consumption [8]. The device might need to run other Bluetooth related tasks, like wireless headphones, in parallel. Because the device can only carry out one task at a time, Bluetooth scheduling is needed [8], which limits the continuous transmission of beacons.

Simulation models

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State-of-the-art mobile apps

2.4.1 Determined. The magnetization ground-states as

RESULTS

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